STUDIES ON THE ICHNEUMONIDÆ OF NEW ENGLAND (HYMENOPTERA)

PART 1[1]

THE EXTERNAL MORPHOLOGY OF AROTES AMŒNUS CRESSON

By Harry D. Pratt

INTRODUCTION

The ichneumon-flies make up unquestionably the largest and most extensive family in the order Hymenoptera, and it is composed of a vast number of minor groups, representing hundreds of genera and thousands of species in North America alone. Unlike other families, the ichneumon-flies, without a single exception, are all genuine parasites, and destroy or devour the eggs, larvæ, pupæ, or imagoes of other insects. Almost every insect, whose biology is known, has at least one ichneumonoid parasite, and the more important economic insects (as the gypsy and browntail moths) have dozens of ichneumon-fly parasites. The family is, therefore, of the greatest economic importance from the viewpoint of biological control, and in some cases, as with the Oriental fruit moth, parasitic control is the only practical type that is used.

Arotes amœnus Cresson was chosen as the subject of this study because it is common throughout New England, so that an abundance of material could be collected for study. It is one of the larger and more primitive of the ichneumon-flies and, for this reason, is well-suited for such a study.

One of the greatest difficulties in the study of the systematic groups is the lack of uniformity in the terminology used to describe the various morphological features of the insects concerned. This fact is especially noticeable in the descriptions of the Ichneumonidæ when one attempts to use the keys of Asmead, Schmiedeknecht, or some of the other nineteenth century taxonomists, whose descriptions are based either on a purely artificial system of termiology (as is the case in the naming of the wing

veins according to the Cressonian system), or on a system containing a great many incorrect terms (as is the case in the misapplication of the terms ''prothorax,'' ''postscutellum,'' ''metanotum,'' and ''metatarsus.''

The great advances which have been made in comparative morphology have made it not only wholly unnecessary, but highly undesirable, to continue such a type of taxonomic work. The following detailed, purely morphological study of one species has been made to serve as a basis for future taxonomic work, and it is hoped that this study will be an aid in determining the morphological status of many structures which have heretofore been misnamed, and in clarifying the terminology used in describing the ichneumon-flies.

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THE HEAD

The head of the male is slightly more than two-thirds the size of that of the female, and its features are less strongly developed than are those of the female. When viewed from in front, the head appears somewhat broader than long and is flattened dorsally along the parietals. In lateral aspect the compound eyes appear to be of almost exactly the same width as the gena. The sutures which demark the areas of the cranium in a typical orthopteroid insect have become obsolescent in *Arotes,* so that the head is remarkable for its lack of sutures. Two of these sutures, the occipital and hypostomal, have been replaced, however, by distinct carinæ which are of great importance in bounding the sclerites of the head.

HEAD CAPSULE

The principal areas of the cranium (Fig. 1) are the *dorsal parietals,* the median facial, or *fronto-clypeal* area, the lateral

genæ, the *occipital arch* (composed of the *occiput* and *postgenæ*) and *post-occiput* surrounding the *foramen magnum,* and the narrow *hypostomal* areas upon which the mouth-parts articulate.

The *parietals* and *fronto-clypeal* areas extend cephalad from the occipital carina between the compound eyes to a line drawn between the *anterior tentorial pits.* The *parietals* (pa) (Fig. 1) include the dorsal surface of the epicranium between the occipital carina and the antennal sclerites, with the exception of the post-frons which is a more or less pentagonal area extending caudad from the antennal sclerites to the median ocellus, as will be explained in greater detail in the discussion of the frons.

The *frons* (af and pf) is a median unpaired sclerite extending from the two anterior tentorial pits to, and including, the median ocellus. According to Crampton (1921), ''When the frontal suture is absent, if a line be drawn across from the top of one antennal fovea to the other, and at either end of this line an angle of forty-five degrees is constructed, the sides of the isosceles triangle thus formed correspond in a general way to the Y-shaped epicranial suture.'' In *Arotes* these antennal foveæ are rather deep depressions which serve for the reception of the scape of the antenna when the antennæ are curved back over the body. These foveæ extend caudad almost as far as do the eyes, and then the frons narrows quite rapidly so as to include the median ocellus.

Because of the noticeable constriction of the frons at the antennæ, Crampton (1921) divides the frons by a line drawn between the bases of the antennæ into an *antefrons* (af) and a *post-frons* (pf). In *Arotes amœnus* such a line occurs naturally, appearing as a darkly-colored hair line extending to the middle of each antennal sclerite, from the distinct carina on the middle of the post-frons. Therefore the *postfrons* (pf) is a roughly pentagonal area extending caudad to the median ocellus, while the *antefrons* (af) is a more or less quadrangular area extending cephalad to the anterior tentorial pits.

For taxonomic purposes, the morphological *antefrons* extending caudad to the base of the antennæ might well be called the ''frons.'' Similarly, the whole dorsal surface of the head could be called the ''vertex,'' since the *postfrons* merges completely with the *parietals* and the epicranial suture has also disappeared

doing away with the necessity of the term "parietals" which should be used for the paired dorsal sclerites. Therefore, for taxonomic purposes in Ichneumonidæ, it would seem best to use but two terms, "vertex" and "frons," for the frontal aspect of the head, and to use the antennæ as the line of division: the dorsal part above the antennæ, the "vertex"; the ventral part below the antennæ, the "frons."

On either side of the true *antefrons* (af) lie the areas known as the *parafrontals* (paf). These extend caudad to the antennal sclerites, cephalad to the base of the mandibles, and laterad to the *ocular sclerites* (asc) and the *subocular suture* (sos). Taxonomically the parafrontals, known as the "inner orbits," are important in specific determinations.

The narrow space separating the compound eye from the base of the mandible, known taxonomically as the "malar space," is a very important character in both generic and specific determinations because its length in relation to the basal width of the mandible is constant. Cushman (1920) calls the *subocular suture,* which arises from the ventral margin of the ocular sclerite and extends ventrad to the dorsal articulation of the mandible, the "malar suture."

The *compound eyes* are large and convex, with their inner margins parallel and not emarginate within, or only very slightly so opposite the antennæ. Their surface is reticulate, being composed of the hexagonal facets of the large number of ommatidia. They are surrounded by narrow, poorly-demarked, elliptical *ocular sclerites* (osc) which extend shelf-like into the head capsule. These chitinous ingrowths appear lens-shaped and are pierced in the middle by a foramen through which the optic nerves pass connecting the optic lobes with the nerve endings of the ommatidia.

The endoskeleton of the head, which braces the lower portion of the head capsule, is called the *tentorium.* In *Arotes* two pair of cuticular invaginations, known respectively as the *anterior* and *posterior* arms of the tentorium, unite within the head to form a framework arching over the ventral nerve cord, but passing beneath the stomodæum and supporting the latter. The *body* of the tentorium, formed by the fusion of the anterior and poste-

rior arms, is not clearly demarked and seems to be composed only of that portion of the tentorium immediately cephalad of the foramen. The *anterior arms* arise from the *anterior tentorial pits.* Each *anterior arm* extends caudad as a long arched chitinous bar to the body of the tentorium, and serves for the attachment of the muscles moving the mouth-parts. The *posterior arms* arise as short invaginations of the hypostomal region, one on each side of the midgular suture. They are barely distinguishable as short chitinous bars before they fuse into the body of the tentorium which lies immediately cephalad of the foramen. The *dorsal arms* are secondary outgrowths of the anterior arms and are strongly developed in *Arotes.* They extend cephalad from the anterior arms to the lateral portions of the antennal sclerites, and serve as points of attachment for the antennal muscles.

The *anterior tentorial pits* (at) (frontal pits of Crampton, 1921) are well defined depressions that outwardly mark the two points from which the anterior arms of the tentorium arise. As determined by a study of the ental surface, the lateral prolongations of these arms extend obliquely ventrad to the base of the mandibles as a pair of lines demarking the clypeus within, but as in most parasitic Hymenoptera (see Snodgrass, 1935, p. 297), these "bars are not connected between the pits." Posteriorly, these epistomal bars are continued externally as strong marginal ridges, differentiated into a *pleurostoma* (plst) bearing the mandibular articulations, and a *hypostoma* (hp) supporting the maxillæ and labium. In the discussion that follows, the pleurostoma is considered as the ventral portion of the gena; while the hypostoma is considered as a separate hypostomal area originally derived from the postgenæ.

The *clypeus* (cl), which is a flat, trapezoidal area extending cepahalad from the anterior tentorial pits to the base of the mandible, is bounded laterally by a line drawn from these depressions to the base of the mandible. The clypeus is slightly inflexed at the apex, but since there are no distinct sutures or carinæ, nor any ental thickenings, it is rather difficult to divide it satisfactorily into a postclypeus and an anteclypeus. Taxonomists usually describe the clypeus as "truncate," but specimens boiled in potassium hydroxide and examined under high magnifi-

cation show that the clypeus is shallowly emarginate with a slight median projection, as is shown in the figure.

The *genæ* (ge) are long, rounded sclerites beneath and behind the eyes and are of about the same width as the compound eyes when seen from a lateral viewpoint. They are not demarked from the parietals but may be said arbitrarily to begin on a line drawn from the most dorsal point of the compound eyes to the occipital and hypostomal carinæ, and to extend anteriorly to the base of the mandible and the subocular suture. The ventral part of the genæ, therefore, is the *pleurostoma* (plst) (Fig. 2) of Snodgrass (1935). Just laterad of the subocular suture is a short, blunt tooth forming the *pleurostomal condyle,* or the cranial portion of the *dorsal articulation* of the mandible. Immediately posterior to this tooth is a distinct emargination and elevation of the chitin. Careful examination with high magnification reveals that there is a corresponding elevation on the mandible, while in between the two lies the slender extensor muscle which opens the mandibles. The reason for this outpouching of the chitin will be explained in the discussion of the mandible. Many taxonomists call the genæ the ''cheeks'' or the ''outer or posterior orbits.'' The coloration and striation of the genæ is much used in the separation of subgeneric groups and species of Ichneumonidæ.

The *occiptal arch.* On the postero-caudal surface of the head (Fig. 2), between the occipital carina and the postoccipital suture, is a horseshoe-shaped sclerite called the occipital arch. Although there is no suture dividing it, the occipital arch is generally said to be composed of a dorsal part, the *occiput* (oc), and the ventro-lateral extensions of this, lying posterior to the genæ, called the *postgenæ* (pg).

The narrow posterior rim surrounding the foramen and demarked from the occiput by a *post-occipitat suture* (pcs) is called the *post-occiput* (pc). Snodgrass (1935, p. 112) suggests that, ''The post-occiput probably is a sclerotic remnant of the labial segment.'' If this statement is true, then the postocciput is the only sclerite entering into the composition of the head to retain the primitive Annelid alignment.

In *Arotes,* since there is no subgenal suture, it seems best to consider the subgenal area as the *hypostomal area* composed of

the narrow marginal area on the sides of the cranium upon which the mouth-parts are articulated and demarked posteriorly by the *hypostomal carina* (hpc). The postgenal region of the cranium has become greatly elongated, thereby creating a long space between the foramen magnum and the base of the mandibles and, at the same time, displacing the labium ventrally by mesal outgrowths of the subgenæ, called the *hypostomal bridge,* so that the bases of the labium and the maxillæ have become united into a labio-maxillary complex. According to Snodgrass (1935) the hypostomal bridge consists of "expansions of the hypostomal parts of the subgenal margin of the cranium and each is separated by a distinct carina from the corresponding postgenal region."

The *hypostomal carina* (hpc) starts at the base of the mandible mesal to the mandibular condyle, and extends posteriorly joining onto the occipital carina and then curving inward towards the foramen where is finally ends on the *midgular suture* determined by the posterior arms of the tentorium. Due to the approximation of the posterior arms of the tentorium on the ventral margin of the foramen, the gula itself has become atrophied and is represented only by the midgular suture.

APPENDAGES OF THE HEAD

The appendages of the head include the antennæ, labrum, mandibles, maxillæ, and labium. Just as the characteristic feature of the head capsule of *Arotes* is the development of the hypostomal bridge, so the characteristic feature of the mouth-parts is the close association or union of the maxillæ, the labium, and the hypopharynx to form the underlip complex, in which the ligula and hypopharynx are combined in a median lobe on which the salivary ducts open.

Each *antenna* (Fig. 4) is composed of about forty segments and may be divided into three principal parts. The first and largest segment, by which the antenna is attached to the head, is termed the *scape* (scp). Externally it has somewhat the shape of a funnel with flaring sides, cut diagonally across the top; internally, it expands into a basal bulb so that the antenna articulates with the *antennal sclerite* (as) by a ball and socket joint

allowing free movement in all directions. The basal bulb has an opening through which run the muscles moving the scape. These muscles have their origin on the dorsal arm of the tentorium, while other muscles arising on the base of the pedicel, move the pedicel and flagellum together, thus controlling the movements of the antennæ. The *pedicel* (pdc), or second segment, is quite short and is sometimes almost hidden from sight, so deeply is it inserted in the scape. The remainder of the antenna is collectively termed the *flagellum* (fl) or *clavola*. The reason for considering the greater part of the antenna as one of the three principal divisions has been explained by Snodgrass (1935, p. 132) who wrote, ''Since the flagellar divisions in Orthopteriod insects increase in number from one instar to the next, they appear to be secondary subdivisions of one primary antennal segment.'' The first flagellar segment is weakly sclerotized a short distance above the base, giving the effect of a very short segment suggestive of the ring-joints of Chalcidoidea and high Hymenoptera, but there is no real articulation or segmentation at this point. The basal flagellar segment is three and one half times as long as broad, and each succeeding segment is somewhat shorter than the preceding one, so that the segment preceding the terminal one is but one and one half times as long as wide. The antennæ, therefore, may be called attenuate. Note that the terminal segment is twice as long as the preceding one, due, most probably, to a fusion of the last two segments.

The *labrum* (lm) is attached (Fig. 1) to the inner surface of the clypeus by membrane and projects below it as a semicircular sclerite. A study of the inner surface of the clypeus reveals that the labrum is attached to the clypeus at about its middle dorsoventrally. The posterior limits of the labrum seem to be determined by membranous thickenings which have their origin just mesad of the dorsal articulations of the mandibles. These membranes curve posteriorly a short distance, paralleling the epistomal bars, and then converge medially and ventrally on the clypeus to form the *epipharynx,* a flexible, triangular membranous lobe which projects below the labrum as a short, sharp, pointed protuberance about as long as the dorsal and outer tooth of the mandibles. Along the apical margin of the labrum, on both the

inner and outer surfaces, are a few long hairs which may be sensory in nature.

The *mandibles* (md) (Fig. 7) are placed just behind the epipharynx, one on each side of the mouth opening. They are of medium size, somewhat curved, and taper apically ending in two blunt teeth, of which the ventral one is the longer, being half again as long as the outer and dorsal tooth. Each mandible has two principal articulations with the head capsule; an *anterior,* or *dorsal articulation,* and a *posterior,* or *ventral articulation.* Both of these are of the "ball and socket" type of joints. The *dorsal articulation* consists of a *pleurostomal condyle* situated just laterad of the *subocular suture* which fits into a shallow socket, or ginglymus, on the mandible. The *ventral articulation* consists of a deep socket on the pleurostomal region of the gena, just cephalad of the hypostomal carina, and *mandibular condyle* (hypocondyle of Crampton, 1921) which fits into this socket. Each mandible is moved by two muscles: an *extensor* or *abductor* muscle which opens the mandible; and a *flexor* or *adductor* muscle which closes the mandible. The *extensor* muscle is relatively small. It is inserted on a chitinous outpouching of the outer face of the mandible between the dorsal socket and the ventral condyle. The outer and anterior face of the mandible is almost flat between the two articulations and parallels the axis line between the two so closely that this outpouching is necessary in order that the base of the extensor muscle be placed sufficiently far outside the axis line to give effectiveness as a muscle. The insertion of the extensor muscle is contiguous to the anterior articulation of the mandible, but it is twice its width from the posterior articulation. The *flexor* muscle is huge and is composed of several bundles of fibers inserted on a large apodeme attached at the inner angle of the mandible almost posterior to the anterior articulation. When not in use the tip of one mandible extends over and covers the tip of the other. There seems to be no special arrangements as to which is outer, for, in specimens examined, the right seemed to cover the left as often as the left covered the right.

The labio-maxillary complex of *Arotes* is attached to the posterior wall of the head between the postgenal margins of the cra-

nium by ample membranes, which allow it free movement on the suspensoria formed by the maxillary cardines. As explained by Snodgrass (1935) a line of flexure crosses the posterior part of this complex through the stipito-cardinal sutures of the maxilla. The basal portion composed of the cardines is bent abruptly toward the head, where it is attached; and the distal portion composed of the labium and the body of the maxillæ lies parallel with the ventral surface of the head. The entire organ can thus be extended by swinging distally on the maxillary cardines. The maxillæ lie one on each side of the labium and are connected to it by the membranous submental area and by maxillary membranes.

Maxillæ (Fig. 6). In each maxilla the *cardo* (cd) is a heavily sclerotized sclerite, somewhat triangular in shape, which tapers to the base and is bent entally. Its extreme base is modified to form two processes which articulate deep in the head capsule with two arm-like projections of the hypostomal bridge, one on each side of the midgular suture. There is apparently no cardocondyle by which the cardo articulates with the post-genal area, but the whole maxilla is capable of some movement due to the concavity of the hypostomal area and the convexity of the cardo and stipes. The *cardo* (cd) articulates with the *stipes* (st) by means of a distinct membranous hinge, and their planes form a distinct angle at the union. The *stipes* (st) is the broad and elongate sclerite forming the body of the maxilla. On its ventral surface is a distinct carina, or ridge, extending diagonally across the stipes from the cardo to the *palpus* (mxplp). There is no trace of the parastipital area. The 5-segmented *palpus* (mxplp) is inserted latero-ventrally on the distal end of the stipes. Just distal to the base of the palpus is attached a large, fleshy lobe called the *galea* (ga), which is distinctly hollowed out for the reception of the lacinia. The *lacinia* (la), which is hinged to the distal end of the stipes, is a large, flat, weakly sclerotized lobe with two slight tooth-like expansions (as is shown in Fig. 6).

Labium (Fig. 5). The labium (lb) is composed of a membranous *submental region* (smt) and a distal *prementum* (prmt) bearing the palpi, glossa, and paraglossæ. The submentum is not sclerotized and probably is situated in the membranous re-

gion attached posteriorly to the stipes at the cardostipital suture and extending anteriorly about two-thirds of the length of the stipes. The *prementum* (prmt) (*mentum* of many authors) is a large, strongly convex, heavily sclerotized plate, the basal and lateral portions of which are strongly produced and bent over so as to extend dorsally to meet the hypopharynx which is situated on the dorsal surface of the labium. The *prementum* (prmt) is expanded centrally and is very convex, sloping abruptly to the glossæ beyond. At about the middle of the prementum are attached the 4-segmented *labial palpi* (laplp) which are only about as long as the first three segments of the maxillary palpi and are much shorter and somewhat more slender than the latter. The *glossa* (gl) is a large, bilobed, membranous pad attached to the distal portion of the prementum. Its apical margin is covered with short, plush-like hair, while the rest of the glossa lacks this covering. The ventral surface of the glossa lacks this covering. The ventral surface of the glossa seems to be longitudinally striate throughout, but the dorsal surface is transversely striate on the distal two-thirds and is smooth and rather heavily sclerotized on the basal third. On either side of this narrow sclerotized base of the glossa occurs a small membranous pad, very similar in structure to the glossa, and these pads apparently represent the *paraglossæ* (pgl). These paraglossæ are closely appressed to the prementum and are best seen from the dorsal view. Viewed from below, they appear as membranous lobes dorsal and cephalad to the palpi (Fig. 6). A membranous papilla-like protuberance, which is the *hypopharynx*, occurs on the median line of the dorsal surface of the prementum just caudal to the base of the glossa. The identity of the hypopharynx is determined by the presence of the opening of the salivary duct at the base of this distinct papilliform protuberance.

NECK OR CERVIX

The neck or cervix connects the head with the thorax and covers the antero-ventral region of the thorax. It is composed of a single pair of plates known as the *lateral cervicals* (lc) (Fig. 9) which articulate with the head by means of the *cephaligers* and with the coxæ by a coxal process.

The *lateral cervicals* (lc) are broad, truncate sclerites, tapering from base to apex, and are joined with membrane along the median line. As shown by Crampton (1926), each lateral cervical results from the fusion of the enlarged lateral cervical, the proepisternum, and the proepimeron; while the prosternum, for which the lateral cervicals have so frequently been mistaken, is represented by a tiny plate partially concealed between the coxæ.

At the anterior end of the lateral cervicals, the *cephaligers* arise on the inner surface and enlarge into knob-like projections which are the actual fulcral points of the head with the cervix.

A blunt, tooth-like projection, which is called the *coxal process,* is found on the ental surface of each lateral cervical near the lateral posterior angle of the sclerite and this projection forms a part of the apparatus for the attachment of the coxa of the fore leg.

THORAX

PROTHORAX

In *Arotes* the prothorax (Fig. 9) consists largely of the *pronotum* (N_1) for the propleura have fused with the lateral cervicals, as explained before in the discussion of the cervix, and the prosternum is reduced to a tiny sclerite lying between the coxæ.

The *pronotum* (N_1) is a narrow transverse plate produced laterally and posteriorly into distinct, triangular lobes which extend posteriorly to the tegulæ, and ventrally to the bases of the fore coxæ. The anterior margin of the pronotum is broadly emarginate, while the posterior margin is arcuately emarginate and overlaps the front margin of the prescutum of the mesothorax (psc_2).

The *prosternum* is a small sclerite composed of an anterior *basisternum* and a posterior *furcasternum*. The triangular basisternum seems to send chitinous processes to the basal end of the lateral cervicals, while the furcasternum forms a broad rounded lobe between the fore coxæ and is the base to which the sternal apophyses of the endoskeleton of the prothorax are attached.

MESOTHORAX

The tergum of the mesothorax (9) is divided into a prescutum, scutum, scutellum, and parascutellum.

The *prescutum* (psc₂) is the large, arched, anterior plate of the tergum which extends cephalad under the pronotum and there gives rise to the prephragma of the mesothorax. It is separated from the scutum by the *notaulices* (usually called the *notauli* by systematists and variously called the V-shaped suture, convergent sutures, or the parapsidal sutures by morphologists).

The *scutum* (sc₂) is the large, rather convex plate rather definitely divided by the notaulices into two lateral portions sometimes called the *parapsides,* to which the *tegulæ* and the wings are attached. Behind the scutum lies the scutellar fovea which is twice as long and contains several indistinct longitudinal carinæ along its middle.

The *scutellum* (scl₂) is twice as long as this scutellar fovea and is connected with the scutum by a chitinous bar on each end of the fovea. Its apex is truncate. The *postscutellum* is hidden beneath the scutellum, where it is fused with the endoskeleton of the mesothorax.

The *parascutellum* consists of two triangular plates extending from the scutum and scutellum to the wing bases, where they form the posterior margin of the fore wing base and the anterior margin of the hind wing base.

The mesepisternal and mesosternal plates are fused into a single sterno-pleural plate making the identification of the lateral and sternal plates rather difficult. Snodgrass (1910) states that the ''mesopectus consists of three principal plates, the combined sternum and episterna, and the two epimera.''

The mesepisternum and mesepimeron were originally separated by a *pleural suture* corresponding to the strong, internal pleural ridge, forming the wing process above and the coxal process below. In *Arotes* this suture is represented by a row of small, pit-like depressions similar to those in *Trogus* which are well shown in the fine figures by Snodgrass (1910). Although this row of punctures is scarcely recognizable as a suture, the presence of the pleural ridge directly beneath it proves that it is the pleural suture, the important landmark on the mesopleura in the division into mesepisternum and mesepimeron.

The *mesepisternum* (eps₂) is the large, more or less triangular plate forming the greater part of the mesopleura. Its anterior

margin lies concealed beneath the lateral portions of the pronotum (N_1) while its posterior, or dorso-caudal, margin, is demarked by the pleural suture extending from the wing base to the coxal process. While the mesepisternum is not definitely demarked from the mesosternum, it is divided into an anterior and posterior part by the *prepectal carina* (pctc). This is a strong, transverse carina originating on the median line of the sternum, which curves posteriorly away from the coxa, and then curves dorso-cephalad on the mesepisternum. Viereck (1916) used the presence or absence of this carina as a primary character for the separation of the various Ichneumonoid families in his Hymenoptera of Connecticut key, but this view is not accepted today by most taxonomists.

The *mesepimeron* (epm_2) is the narrow band lying dorso-caudad of the mesepisternum and separated from it by the pleural suture.

The *mesosternum,* as already mentioned, is fused with the mesepisternum to form a single sterno-pleural plate and there is no line of demarkation between the two areas.

Along the median line of the sternum, starting at the prepectal carina, there is a row of pit-like depressions which outwardly mark the line of attachment of the apophyses of the mesothoracic endoskeleton. The pleurosternal plate is modified posteriorly to form a *coxal process* projecting into the mesothoracic coxal cavity from its antero-median margin, while the *pleural coxal process,* formed at the end of the pleural ridge, projects into the coxal cavity from the postero-lateral margin thus forming the two points of articulation for the mesathoracic leg.

Mesad of the coxal cavities lies a triangular sclerite known as the *furcasternum* which is poorly demarked by carinæ from the rest of the mesosternum (eusternum of the mesothorax). This is deeply invaginated along the median line and bears the internal structure called the *furca*.

METATHORAX

The tergum of the metathorax (Fig. 9) is composed of four sclerites which are called the prescutum, the scutum, the scutellum, and the postscutellum (all designated in figure 9 as N_3).

The *prescutum* is the depressed area directly behind the meso-scutellum and attached beneath it to the mesopostscutellum. It merges into the large, convex plate composed of the fused *meta-scutum* and *metascutellum*. This plate has usually been called the "postscutellum" or "metanotum." Crampton (1931), how-ever, has shown that in the closely allied genus *Megarhyssa* the large dorsal plate lying directly posterior to the prescutum is the *metascutellum* while the narrow saddle-like band extending over the tergum between the metascutellum and the propodeum is the *metapostscutellum*.

The *metapostscutellum* curves cephalad as a narrow band forming the posterior margin of the hind wing base and at the lower margin of the wing base fuses with another narrow sclerite.

This last plate, which lies between the wing base and the meta-thoracic spiracle (sp_3), Crampton (1931) has shown to be com-posed of the fused *anepisternum* and *anepimeron* of the meta-thorax (aes_3 and aem_3). Below the spiracle the band widens out into a broad, slightly convex plate, usually called the "meta-pleura," but actually composed of the *katepisternum* and *katepi-meron* of the metathorax (kes_3 and kem_3).

The lateral longitudinal carina extending cephalad from the metathoracic coxal cavity to a point just posterior to the meso-thoracic coxal cavity seems to mark the line of division between the metapleural and metasternal regions. On the metasternum the line of attachment of the sternal apophyses is clearly demarked.

THE WINGS

The system of wing venation proposed by Ross (1936) has been used in this paper in preference to the artificial Cresson system usually used by taxonomists, or the Comstock-Needham system which is often figured in the older text-books. The system pro-posed by Bradley (1931) is somewhat similar to that of Ross (1936), but the latter seems to have worked out the origin of the main veins, particularly in the posterior portion of the wing, more carefully and on sounder grounds—*i.e.*, axillary sclerites instead of axillary furrows—and, for this reason, the Ross (1936) interpretation is used in this paper. The discussion of the wings follows the interpretation which Dr. Ross outlined to me in a

letter dated December 22, 1936, while the drawings of the wings are exact copies of a figure which he labelled at the same time.

FORE-WINGS

Costa (C) (Fig. 12) forms the thickened anterior, or front, margin of the wing. It arises just distad of the basicostal plate and extends along the anterior margin of the wing to the pterostigma, from which it is separated by a distinct break, the costal hinge.

Subcosta (Sc), present in the wings of primitive sawflies, has frequently been considered as fused into a ''principal vein'' with radius and media, but Bradley (1931) writes, ''It is both simpler and more probably truthful to consider that it has atrophied entirely . . . therefore the marginal vein should be labelled C.'' Many writers have shown that Sc_1 becomes atrophied at an early stage in the phylogeny of the Hymenoptera, either in the Cimbicidæ or in the Siricidæ, while in the primitive *Macroxyela* type Sc_2 becomes separated from R_1 and extends along the anterior margin of the wing forming with R_1 the cell Sc_2 and R_1. This cell has been retained in the intermediate forms becoming gradually thickened and growing by fusion, so that in *Arotes* the cell labeled Sc_2 and R_1 is actually the pterostigma, or ''stigma.'' The break in the chitinization just before the pterostigma is called the *costal hinge*. It marks not only the termination of costa and the point at which Sc_2 attains the costal margin of the wing, but also indicates the point at which the radial sector turns inward.

Radius (R) is the second longitudinal vein. It forms the posterior margin of the very narrow costal cell, a cell so narrow that in most family keys to the Hymenoptera it is regarded as absent or ''lost through coalescence,'' in contradistinction to the much wider costal cell of Aulacidæ and Gasteruptionidæ. Basally radius (R) (which is united with costa before the latter articulates with the basicostal plate) articulates with the second axillary sclerite. R forks but once, giving off an anterior branch R_1 (which marks the posterior margin of the stigma and continues beyond the stigma along the anterior margin of the wing, and a posterior branch, the radial sector (Rs), which fuses with the

first abscissa of Media just basad of the costal hinge. In all the Chalastogastra the first abscissa of Rs + M (indicated in the figure by the dotted line) cuts across the cell R_5 + 1st M and touches the first medio-cubital cross-vein (1 m–cu) ; but this first abscissa of Rs – M has been lost in all Ichneumonidæ and only a spur, called the *ramellus*, remains to prove the former existence of such a vein, as in *Cryptus* and *Exetastes*. In *Arotes* this spur is very tiny. Rs + M now extends antero-distad for a short distance and then divides into Rs and M, with Rs forking at almost a right angle just beyond 2 m–cu and then continuing in a gentle arc to the apex of the wing where it joins R_1 to form cell R_1.

The cross-vein arising from the middle of the stigma, and connecting it with the radial sector, is the second radial cross-vein 2r.

The *areolet*, present in the wings of most Ichneumonidæ, is formed with the first abscissa of radius by the second radio-medial cross-vein.

Media (M), fused basally with cubitus, forms the third longitudinal vein. At its origin, media forms part of the compound vein complex just distad of the basicostal plate (bp), and is more definitely associated with the median plate (m). Just distad of the pteralia, media and cubitus separate from radius and proceed postero-distad along the basal third of the wing. Here media and cubitus fork, cubitus continuing to the anal angle, while media turns abruptly toward the stigma and joins the radial sector (Rs) a short distance from the costal hinge. (Note that according to the Ross interpretation, media never actually attains the base of the stigma, or the costal margin, although it does come very close.) As previously explained, Rs + M cuts across the cell R_5 and 1st M in the primitive Hymenoptera, but this abscissa of Rs + M has atrophied leaving only the tiny stump to mark its former location. From here Rs + M proceeds antero-apicad dividing abruptly into the radial sector (Rs), which eventually attains the apex of the wing, and M which extends in a gentle arc to the outer margin of the wing.

The first and second medio-cubital cross-veins connect the medial and cubital fields, 1 m–cu marking the terminus of the first abscissa of Rs + M and 2 m–cu marking the terminus of the second abscissa of Rs + M.

Cubitus (Cu), as explained previously, is associated with the base of radius and media, so that actually none of the four principal veins, namely costa, radius, media, and cubitus, arise independently. Cubitus apparently articulates with the anterior-distal corner of the median plate (m), and after proceeding for the basal third of the wing as a fused vein with M, divide into M and cu. Ross, following Tillyard's hypothesis of the loss of Cu_2 in the fossil *Permoraphidia* and *Martynovia*, and the resultant carry-over in modern Holometabola, believes that Cu_2 has been lost in Hymenoptera and that the apical division of Cu should be called merely a division of Cu_1, with an anterior branch Cu_{1a} and a posterior branch Cu_{1b}.

The first cubito-anal cross-vein (1 cu–a) lies between cubitus and the first anal vein and connects the cubital and anal fields. The position of 1 cu–a with reference to the first abscissa of M is of considerable taxonomic importance, *i.e.*, whether 1 cu–a (called the nervulus by taxonomists) is opposite M (interstitial), proximal to it (antefurcal), or distal to it (postfurcal).

Anal Veins. The homologies of the anal veins are indeed a difficult problem. According to Ross (1936), there were originally four anal veins in the *Macroxyela* type, all articulating with the third axillary sclerite. In the lower Hymenoptera—*Macroxyela* as figured by Ross (1936) and *Itycorsia* (a pamphilid) as figured by Snodgrass (1910)—the bases of these anal veins are all distinct and separate. In the higher sawflies, however, a fusion of the bases of these anal veins begins to develop, associated with the dropping out of the second anal vein. In the Ichneumonidæ, as shown by *Megarhyssa* and *Arotes,* this fused base of the anal veins becomes very large and triangular in shape as a result of the fusion of the anals and only the first anal remains distinct. Both Snodgrass (1910) and Ross (in a personal letter) have shown that in Ichneumonidæ this is the *first anal vein* (1A). The second anal vein has dropped out in the sawflies (Ross, 1936) while the third anal vein has been identified as the tiny stub in the basal membrane arising from the middle of the fused base of the anals. The fourth anal vein is present only in the members of the Xyelidæ, and even in them is represented by only a tiny stump in the basal membrane.

The *first anal vein* (1A) is the fourth longitudinal vein and follows almost a straight course parallel to the inner margin of the wing, ending some distance before the anal angle of the wing.

The anal fold, or furrow, lying anterior to the first anal vein is indicated in the figure by a dotted line. It is clearly demarked by a line of dark setæ, which contracts strongly with the hyaline membrane at the base of the wings. As it extends to the anal angle of the wing, this anal fold breaks the chitinization of the veins 1 cu–a and Cu_{1b}, and the resulting membranous areas in these veins are called *bullæ*. There are three other bullæ in the fore-wing, one in the middle of the second abscissa of $Rs + M$, and the two others about equidistant from each other on the second medio-cubital vein (2 m–cu).

HIND WINGS

Although at first glance the venation of the hind wing (Fig. 13) appears to be radically different from that of the fore-wing, yet a closer examination shows that the scheme of modification has been essentially similar in both wings.

Costa (C) is the slightly thickened, anterior margin of the wing, extending at most only along the basal third of the wing.

Subcosta (Sc) is completely fused with radius.

Radius (R) divides into R_1 (which bends toward the anterior margin of the wing, and attains it, at the apical third) and Rs, which attains the outer margin of the wing just below the apex of the wing.

The *radio-medial cross-vein* (r–m) connects the radial sector (Rs) with the medial field (M).

The *hamuli*, a row of a dozen tiny hooks which fit into a pocket in the fore wings and hold the two wings together in flight, are borne on the basal part of R_1.

Media (M) separates from radius near its base, fuses with Cu_1 for a considerable distance, then separates from it and proceeds to the margin of the wing. It is connected to Rs by r–m, but the medio-cubital cross-veins are lacking.

Cubitus (Cu) is represented only by Cu_1, which does not divide into Cu_{1a} and Cu_{1b}, as in the fore wing, but continues to the margin of the wing simply as Cu_1. It is fused to Media to about

the middle of the wing and then separates sharply at a right angle, until it touches the cubito-anal cross-vein (cu–a), at which point it again becomes a longitudinal vein which parallels M to the outer margin of the wing.

Cu_1 and cu–a make up the very important structure known to taxonomists as the *nervellus*. In using this important structure for the separation of genera and species, taxonomists have three alternatives: it may be "broken above the middle," *i.e.*, first abscissa of Cu_1 shorter than cu–a; it may be "broken at about the middle," *i.e.*, first abscissa of Cu_1 about equal to cu–a; or it may be "broken below the middle," *i.e.*, first abscissa of Cu_1 longer than cu–a.

In *Arotes* taxonomists describe the nervellus as "broken at about the middle, and reclivous." This last term was first defined by Cushman and Rohwer (1920) with two other alternatives, as follows:

"A *perpendicular nervellus* is one in which the anterior end is opposite the posterior end, that is, one in which a line drawn touching both the anterior and posterior ends is at right angles to the longitudinal axis of the submediallan cell (Cell R_5). Other authors have called this a continuous or interstitial nervellus.

"An *inclivous nervellus* is one in which the anterior end is nearer the base of the wing than is the posterior end. This has been spoken of as a postfurcal nervellus.

"A *reclivous nervellus* is one in which the posterior end is nearer the base of the wing than is the anterior end. This has heretofore been spoken of as a postfurcal nervellus."

The *anal furrow* is indicated in the figure by a dotted line. Behind it lies a distinct longitudinal vein arising from the third axillary (3 Ax). This is the *first anal vein* (1 A).

Behind this first anal vein, extending into the first anal cell is a tiny spur of the *third anal vein* (3A).

PTERALIA OF THE FORE-WING

Each wing is attached to the thorax by a membranous basal area containing several tiny sclerites which Snodgrass (1935) has called the *pteralia*. These include in Hymenoptera an anterior *basicostal plate* (which Snodgrass calls the *humeral plate*), a

group of four *axillary sclerites,* and a single *median plate* (which would seem to be the outer median plate, labeled m′ by Snodgrass (1935, p. 219)).

In the fore wing (Fig. 11) the *basicostal plate* (bp) lies between the anterior notal process and the base of costa. It is a large plate resembling a second tegula somewhat and has a deep suture crossing it diagonally so that there appear to be two basicostal plates.

The *first axillary sclerite* (1 ax) is a peculiar twisted sclerite which articulates on its inner margin with the thorax and on its outer margin with the axillary sclerites and the base of the principal veins. Its inner margin articulates with the anterior notal process and with the tergal margin. On its outer margin, its anterior process forms a fulcral point for the basicostal plate and the second axillary, and on its under side it apparently also forms a fulcral point for a portion of the enlarged base of costa, radius, media, and cubitus.

The *second axillary sclerite* (2 ax) is hinged obliquely to the outer margin of the first axillary. Anteriorly it articulates with the base of radius and media (and through these with costa and cubitus) and with the median plate. Posteriorly, the second axillary articulates with the median projection of the third axillary.

The *third axillary sclerite* (3 ax) lies in the posterior part of the articular membrane just before the *axillary cord.* Anteriorly it articulates with the enlarged, triangular base of the first and third anal veins, mesally with the posterior end of the second axillary, and posteriorly with the fourth axillary.

The *fourth axillary sclerite* (4 ax) is a small sclerite lying between the third axillary and the posterior notal process.

The *median plate* (m) is probably the distal median plate labelled m′ by Snodgrass (1935, p. 219). It is a triangular plate lying in the median area of the articular membrane. By its basal corner it articulates with the second axillary; but its anterior-distal corner, with the base of Cu; and by its posterior-distal corner, with the large, triangular base of the first and third anal veins.

PTERALIA OF THE HIND WING

The pteralia of the hind wings (Fig. 10) are similar to those

of the fore-wings.   There is apparently no tegula in the hind wing and the base of the wing continues simply the articular membrane.

The *basicostal plate* (bp) articulates by its apex with the combined bases of costa, radius, media, and cubitus.

The *first axillary sclerite* (1 ax) is a V-shaped sclerite which articulates with the basicostal plate by its anterior process and with the second axillary by its posterior arm.

The *second axillary sclerite* (2 ax) in addition to its articulation with the first axillary, articulates by its anterior corner with the fused base of radius and media.

The *third axillary sclerite* (3 ax) articulates anteriorly with the base of the anal vein, mesally with the second axillary and posteriorly with the posterior notal process.   There is no fourth axillary in the hind wing, as shown by Salman (1928) and Snodgrass (1910).   Posterior to the third axillary the membrane is thickened to form the *axillary cord*.

The *median plate* (m) articulates posteriorly with the fused base of media and cubitus, and more particularly with the latter, and anteriorly with the base of the first anal vein.

CELLS OF THE WINGS

The names of the various cells have been figured by Cresson (1887), Comstock (1930), Bradley (1931), and Ross (1936).   A comparison of the various systems as they apply to *Arotes* is given below.

Cells of the Fore Wing

Cresson	Comstock-Needham	Bradley	Ross
Pterostigma	Pt	$Sc_2 + R_1$	Sc_2
Marginal, or Radial	2nd $R_1 - R_5$	2nd $R_1 + R_5$	2nd R_1
Cubito-discoidal	M_4	1st M_4 + 1st R_1	1st R_1 + 1st M
Median	M	M	R
Third Submarginal	R_5	1st + 2nd + 3rd R_5	R_5
First Apical	2nd M_2	2nd M_4	Cu_{1a}
Second Apical	M_1	2nd M_2	3rd M
Second Discoidal	Cu_1	Cu_1	Cu_{1b}
Third Discoidal	1st M_2	1st M_2	2nd M
Submedian	Cu	Cu + 1st A	Cu_1
Anal	A	2nd A	1 A

Cells of the Hind Wing

Costal	C		C	C
Median	M		M	R
Radial	$R_1 + R_2$		R_1	R_1
Cubital or submarginal	R_5		R_5	R_5
Submedian	$M_4 + 1st$	$M_2 + M_1$	$M + Cu + Cu_1$	$1st\ Cu_1$
First Discoidal	M_1		M_2	M
Second Discoidal	M_2		M_4	$2nd\ Cu_1$
Anal	1st A		2nd A	1st A

THE LEGS

The legs are rather long and slender in proportion to the size of the body. The front pair is the smallest while the hind pair is the longest and largest, the hind femora of the male reaching to, or almost to, the tip of the abdomen.

Each leg (Fig. 8) is made up of a rather large *coxa* (cx), a distinct two-segmented *trochanter* (tr), a rather short and almost cylindrical *femur* (fe), an elongate *tibia* (ti), a five-segmented *tarsus* (ta), and a *pretarsus* (ptar) bearing a pair of claws.

In the hind legs the coxæ are almost pear-shaped. On the large basal end, each coxa is deeply incised on its postero-laterad surface by a *basicoxal suture*. The narrow band of chitin thus demarked expands above this suture into a semi-globular *basicoxite* which fits into the metathoracic coxal cavity, so that the articulation strongly resembles a ball and socket joint. The coxo-trochanteral articulation is dicondylic, for the distal end of the coxa is emarginate on either side and into these emarginations fit peg-like projections of the trochanters, sometimes known as *trochanter-condyles* acting as pivotal points. Posteriorly a levator muscle is attached to the trochanter; anteriorly the depressor muscle is attached.

The *trochanter* (tr) is almost as long as the coxa but is more slender and almost cylindrical. As in all Ichneumonidæ, the *trochanters* are two-segmented. Cushman (1929) calls the apical segment the *trochantella,* which is a very appropriate term since in this genus and in most other Ichneumonidæ the second segment is the smaller of the two segments. Snodgrass (1935), by a study of the muscle attachments, has shown this two-segmented trochanter is formed not by a division of the trochanters (as in Odonata) but by a basal subdivision of the femur; and Crampton (1925) thinks it is preferable to call this segment the

basifemur ''rather than by the terms which imply that it is a part of the trochanter.'' The two segments are joined to each other by an *articular membrane.*

The *femur* (fe) is a strong, robust segment attached by articular membrane to the trochanter along a trochantero-femoral hinge. It is perhaps the most important leg segment from a taxonomic viewpoint because the coloration of this segment offers primary characters for the separation of the eight species of *Arotes* occurring in North America. The femora-tibial articulation is similar to that between the coxa and trochanter. The pivotal points of the femur, sometimes known as the *tibiafers,* are found on the anterior-lateral portions of the apical margin. Basad of this articulation, the proximal end of the tibia is produced into a distinct head, called the *tibiacaput* (Crampton, 1923), which is received in a distal pocket of the femur or the ''femur cup.'' This device allows the tibia to be inflexed close to the under side of the femur.

The *tibia* (ti) is the longest and slenderest segment of the leg. It is narrower at the base and gradually expands toward the tip where it is of about the same diameter as the trochanter. On the apical margin of the tibia are two immovable spines about as long as the third tarsal segment. The mid tibia is similar to the hind one, both bearing two immovable, apical spines usually known as *tibial spurs.* The fore tibia, however, is relatively broader at the apex and bears on its apex one movable spine which is modified to form a part of the *antennal cleaner.* This spine is drawn between it and the modified inner basal surface of the basitarsus. The apex of the tibia is hollowed out to form a *tibiatheca,* or cup of the tibia, which receives the head of the basitarsus; so that the tibio-tarsal joint is in the nature of a ball and socket joint.

The *tarsus* (ta) is composed of five segments, of which the basal one, known as the *basitarsus* (formerly *metatarsus*), is as long as the next three segments together. The tarsal segments each expand slightly from base to apex. They are clothed with a fine short pubescence, but I have seen no trace of tarsal pulvilli or *euplantulæ.* The fourth tarsal segment (ta$_4$), which is the shortest segment of the tarsus, is half as long as the apical tarsal segment. The subsegments of the tarsus are freely movable on

one another by inflected connecting membranes, but apparently as Snodgrass (1935) states, "the tarsus never has intrinsic muscles."

The fifth tarsal segment, or *distitarsus,* bears the *pretarsus* which is composed of two lateral claws and a complex series of structures between them.

The dorsal surface of the distitarsus (Fig. 14) bears on its apical margin a triangular-shaped sclerite, the *unguifer* (uf) to which the claws, or *ungues* (un), are attached.

On the ventral surface of the distitarsus, and partially concealed by it, lies a median plate, the *unguitractor* (ut). On its base it bears an *apodeme* (ap) to which is attached the depressor muscles of the pretarsus, often called the *retractor of the claws.*

The claws, or *ungues* (um), which are attached by flexor membrane to the unguifer and unguitractor, are large and curved. Each claw is noticeably cleft at the apex and typically bears two or three long spines on its base just laterad of the flexor membrane. The *planta* (pl) is a rather broad sclerite attached distally to the unguitractor plate. It is rather easily seen because of the three or four setæ it bears.

The *orbicula* (or), which is apparently attached to the unguifer, lies above the planta on the dorsal surface, and the girdle-like *camera* lies between the two.

The *camera* (cm) is a heavily sclerotized band which by its contractions and expansions changes the *arolium* (ar) from a small, membranous pad into a large, bilobed structure.

THE ABDOMEN

The *propodeum* (Fig. 3), long, erroneously, called the "metanotum" by taxonomists, is morphologically the tergite of the first abdominal segment. It is derived entirely from the tergum, the pleural and sternal plates having become atrophied as explained by Crampton (1931). Its hind margin broadens out into a semicircular band forming the dorsal half of the aperture through which the petiole of the abdomen projects and articulates with the thoracic region.

The *propodeal spiracles* are situated on the anterior lateral margin of the propodeum. These are long, oval, or slit-like spiracles, as contrasted with the short oval, or circular spiracles

of *Coleocentrus,* the other genus in the Acoenitini.   The spiracles are about twice their own length from the base of the propodeum, and are connected with the base by carinæ.

Various systems of naming the areas of the propodeum have been proposed from time to time.   The systems introduced by Davis (1897) and by Morley (1903) seem to be most used by modern taxonomists, and for this reason are used in this paper.

1. Basal, or first median area (basareola)
2. Superior, or second median area (areola)
3. Apical, petiolar, or third median area (petiolarea)
4. External, or first lateral area
5. Area dentipara, external median, or second lateral area
6. Internal, middle apical, or third lateral area
7. Spiracular, or first pleural area
8. Lateral, middle pleural, or second pleural area

Snodgrass (1935) divides the abdomen proper into three groups: The *pregenital,* or visceral segments which, in *Arotes,* comprise the second to seventh segments; the *genital segments,* composed of the eighth and ninth segments in the female, and the ninth in the male; and the *postgenital segments.*

The abdomen in both sexes is slightly petiolate at the base. In the *male* (Fig. 17), the abdomen is more or less cylindrical throughout, expanding but slightly from base to apex, and is only slightly compressed apically.   The abdomen of the *female* (Fig. 15) is cylindrical at the base, but expands medially, and becomes compressed from side to side on its apical third, in a manner suggestive of the Ophioninæ.   The most remarkable feature of the female abdomen (and the structure by which the female Acoenitini may be at once separated from all other Ichneumonidæ) is the very large vomeriform hypopygium which is heavily sclerotized and acute at the apex.

The abdomen consists of nine distinct segments, exclusive of the propodeum, which is the true first tergite, and it is possible that the membranous area around the anus may well represent the eleventh tergite, in which case the abdomen proper is composed of ten segments.

The connection between the abdomen proper and the propodeum is made by the insertion of the basal end of the petiole, or true second abdominal segment, into the aperture formed by

the propodeum and the metasternum. The petiole apparently articulates with the propodeal part of this aperture by lateral projections of the base of the petiole. On the base of the petiole lies a median, dorsal ligament, called the *funicle,* which is attached anteriorly to the endoskeleton of the metathorax by muscles, and acts as a levator of the abdomen.

The *petiole,* or second abdominal segment (2t), according to Crampton (1931) is composed entirely of the second tergite which has extended ventrally and fused in the anterior region, crowding the second sternite (2s) backward in the process. The petiole is about three times as long as it is wide at the apex, and expands from base to apex. The oval spiracles lie in the middle of the petiole.

Female Abdomen

In the female (Fig. 15), the tergite is bent at its basal third, and is produced into a small protuberance somewhat similar to the large basal protuberance in the petiole of such Mutillidæ as *Dasymutilla.* The *second pleurite* is a narrow, longitudinal band of membrane originating beneath the spiracle, and extending caudad to the third pleurite. It is demarked by a fold from the membranous *second sternite.*

The third to fifth abdominal segments are similar in general form and structure, each consisting of a tergite, sternite, and a pair of sclerites of uncertain affinities, which in this paper are called the *pleurites.* These three segments increase noticeably in size and sclerotization as they extend caudad. The tergites grow successively shorter, wider, and more convex; the pleurites become more strongly sclerotized; and the sternites show larger sclerotized areas in the sternal membrane.

In the sixth segment, the *tergite* (6t) fuses with the pleurite. The spiracle of the sixth segment, however, is just as far from the latero-pleural line as are the spiracles of the three preceding segments (which fact may indicate either that the pleurites are of recent origin, or more probably that the fusion of the sixth tergite with the pleurite has taken place quite recently), whereas the spiracles of the seventh, and eighth segments are quite near the latero-pleural line. The sixth sternite is almost completely sclerotized.

In the seventh abdominal segment, the tergite is similar to that of the sixth. The seventh segment is the largest segment of the abdomen, and combines the two features by which the females of this tribe are easily told from all others: the abdomen begins being compressed from side to side with the seventh tergite, and the *seventh sternite* (7s) is enormously elongated, very heavily sclerotized, and acute at the apex, producing what taxonomists call "the large, vomeriform hypopygium characteristic of the tribe Acoenitini." It is about one-third as long as the whole abdomen, or about as long as the three preceding segments together. This plate is concave, so that the ventral portions of the genitalia fit into it, and are concealed and protected by it. For this reason, it is often called the *subgenital plate* or *hypopygium*.

FEMALE GENITALIA

The genital segments of the female (Fig. 16) are composed of the eighth and ninth tergites and their appendages, for in *Arotes,* as in all Hymenoptera, there are no pleural or sternal plates on these segments in the females. The *eighth tergite* (8t) is slightly smaller than the seventh and its spiracle lies on the anterior edge of a distinct fovea. The *ninth tergite* (9t) is an elongate plate forming the fulcral point for both the ovipositor and the valves of the ovipositor. It has no spiracle.

The basal part of the *ovipositor* consists of the *first* and *second valvifers* (1 vf and 2 vf), which lie beneath the ventral margin of the ninth tergite. The *first valvifer* articulates by its dorsal angle with the ninth tergite, and by its posterior, ventral angle with the second valvifer. Anteriorly, the first valvifer has the form of a very thin, transparent plate, which is continuous with the ramus of the first valvulæ.

The second valvifer (2 vf) is a narrow, elongate plate, which lies half hidden beneath the ninth tergite. Anteriorly, it widens into a large, rounded process articulating with the first valvifer so that there is actually no articulation with the ninth tergite as in most typical insects; posteriorly, it broadens very slightly and becomes modified to form the long, slender *third valvulæ* (3v). It is continuous with the ramus of the second valvulæ along its extreme anterior margin, and its antero-dorsal margin

is produced into a long, pointed apodeme for the attachment of muscles.

The shaft of the ovipositor is elongate and compressed with an acute apex. The *ovipositor* itself is composed of the *first* and *second valvulæ* (1 v and 2 v) which form respectively the ventral and dorsal parts of the ovipositor. The apical portion of the ovipositor is usually enclosed between the concave *third valvulæ* (3v) which are often called the *valves* or *sheaths of the ovipositor*.

POSTGENITAL REGION

This is a membranous, apical area surrounding the anus. At the base there are weakly sclerotized dorsal and ventral sclerites which may represent the *tenth tergite* and *sternite* (10t and 10s) (Figs. 15, 16, 17). The *cerci* (ce) are borne in the membranous area between them and the *anus* at the extreme apex.

MALE GENITALIA

In *Arotes* the copulatory ossicles are located on the ventral side of the genitalia, and studies of the more primitive *Macroxyela* and certain Cephid genera would indicate that this is the more primitive, *orthandrous* condition, and that the torsion of the parts that occurs in some sawflies in the family Tenthredinidæ is a secondary development characteristic of the Tenthredinid complex called the Strophandria by Crampton (1919) and by Ross (1937).

The *basal ring* (br) (Figs. 18, 19) is a narrow, basal band enclosing the rest of the genitalia. According to Snodgrass (1935, p. 605), "it is said to differentiate as a circular fold of the wall of the genital chamber."

The *genital claspers,* or *parameres,* were first homologized with the parameres of Coleoptera by Wheeler in 1910, and his views on the subject have been accepted by Pruthi (1924), Balfour-Brown (1932), Snodgrass (1935), and Crampton (1936). The *parameres* (pr) arise on the ventral side of the basal band or ring and expand laterally into wide basal plates, which narrow again on the dorsal side meeting along a dorso-median caudal groove. Apically the parameres are lengthened into blunt, tooth-like projections which serve somewhat similar functions as the distal

segments of the parameres in lower saw-flies. These tooth-like projections, however, are probably not homologous with the distal segments of the parameres (which Crampton, 1919, called the *cochlearia* in the lower saw-flies) since these distal segments seem to drop out in the phylogeny of the Hymenoptera at about the Cephid level.

The *copulatory ossicles* are composed of a large basal portion known as the *volsella* (vol) and a smaller, slightly cylindrical apical segment called the *sagitta* (sag), which is connected to the volsella by membrane and is the true copulatory ossicle. They arise mesally on the parameres and project posteriorly, one lying on either side of the ædeagus. It should be emphasized especially, however, that in *Arotes* and also in *Coleocentrus,* which two genera comprise in America the tribe Acoenitini of Cushman and Rohwer, there is no *distivolsella*. Therefore, the inner forceps structure is lacking, although it is present in all the other Ichneumonidæ known to the present writer. The absence of the distivolsella in these two genera would seem, therefore, to be a character of tribal value in separating the Acoenitini from the other tribes of Ichneumonidæ, and it is possible that this character may be correlated with the huge development of the plow-shaped, or vomeriform, hypopygium in the female.

The central structure of the male genitalia is the *ædeagus,* which is composed of a pair of *penis valves* (ae). At the base of the ædeagus, on the dorsal side are a pair of *parapenes* (pap) which help to strengthen the pallic structure.

Postgenital Segments

The postgenital segments (Fig. 17) are membranous but do include small sclerotized areas which would seem to be the tenth and eleventh tergites (10t and 11t) and the corresponding sternite. Snodgrass (1935) and other writers would call the small cercus-like appendages of the postgenital segments *socii* and would homologize them with similar structures in Trichoptera and Lepidoptera, but it is more reasonable to compare these appendages with those of male Mecoptera (since the genitalia of Hymenoptera are closest to those of Mecoptera) and to call them

true cerci as Crampton (1936) has done.   The *anus* is situated at the very apex of the abdomen in both sexes.

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LIST OF ABBREVIATIONS

ae	—aedeagus		o	—ocellus
aem	—anepimeron		oc	—occiput
aes	—anepisternum		or	—orbicula
af	—antefrons		osc	—ocular sclerite
ap	—apodeme			
ar	—arolium		p	—pleurite
as	—antennal sclerite		pa	—parietals
at	—anterior tentorial pits		paf	—parafrontals
ax	—axillary sclerite		pap	—parapenes
			pc	—postocciput
bp	—basalar plate		pcs	—postoccipital suture
br	—basal ring			
			pctc	—prepectal carina
C	—Costa		pdc	—pedicel
cd	—cardo		pf	—postfrons
ce	—cercus		pg	—postgena
cl	—clypeus		pgl	—paraglossa
cm	—camera		pl	—planta
Cu	—Cubitus		plst	—pleurostoma
Cx	—coxa		ppct	—prepectus
			pr	—paramere

epm   —epimeron
eps   —episternum

fe   —femur
fl   —flagellum

ga   —galea
ge   —gena
gl   —glossa

hp   —hypostoma
hpc   —hypostomal carina

kem   —katepimeron
kes   —katepisternum

la   —lacinia
laplp —labial palpus
lb   —labium
lc   —lacinia
lm   —labrum

M   —Media
m   —median plate
m-cu —medio-cubital cross-vein
md   —mandible
mxplp—maxillary palpus

n   —notum

prmt —prementum
psc   —prescutum
pscl —postscutellum
ptar —pretarsus

R   —Radius
Rs   —radial sector

s   —sternite
sag   —sagitta
Sc   —Subcosta
sc   —scutum
scl   —scutellum
scp   —scape
smt   —submentum
sos   —subocular suture
sp   —spiracle
st   —stipes

t   —tergite
ta   —tarsus
ti   —tibia
tr   —trochanter

uf   —unguifer
un   —ungues
ut   —unguitractor

v   —valvula
vf   —valvifer
vol   —volsella

Plate V

Figure 1. Dorsal view of the head.
Figure 2. Ventral view of the head.
Figure 3. Dorsal view of the propodeum.
Figure 4. Antenna.
Figure 5. Labium.
Figure 6. Maxilla.
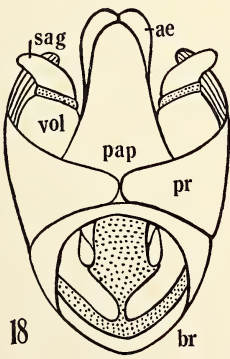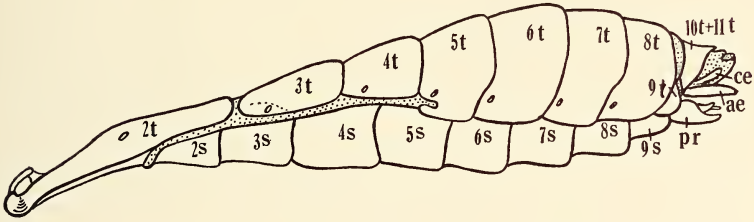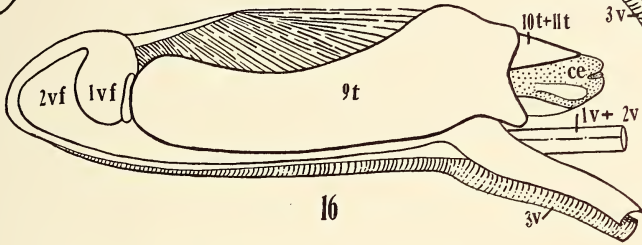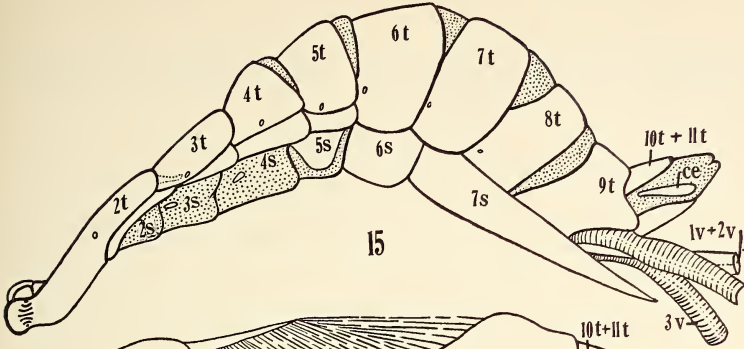Figure 7. Mandible.
Figure 8. Fore Leg.
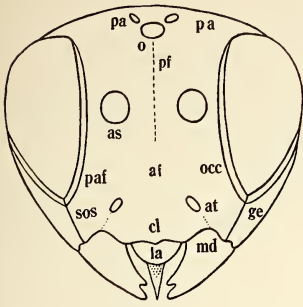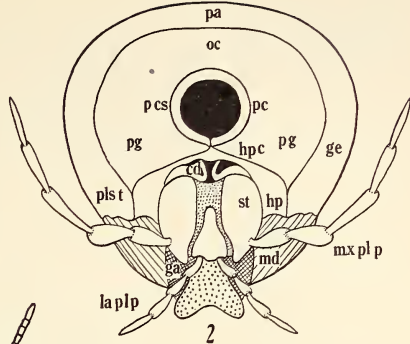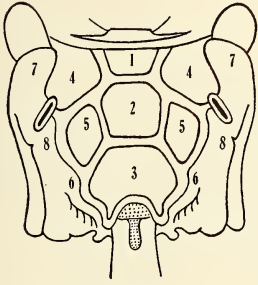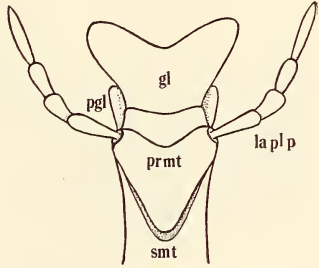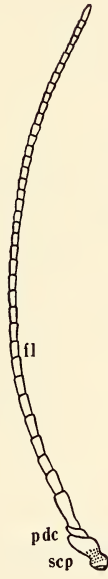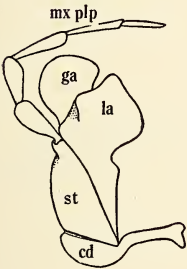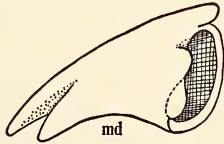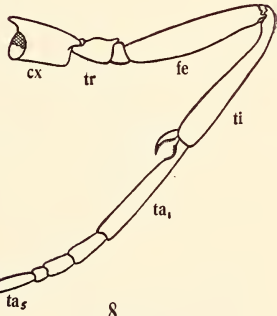
PLATE VI

Figure 9. Lateral view of the pro-, meso-, and metathoraces.
Figure 10. Pteralia of the hind wing.
Figure 11. Pteralia of the fore wing.
Figure 12. Fore wing.
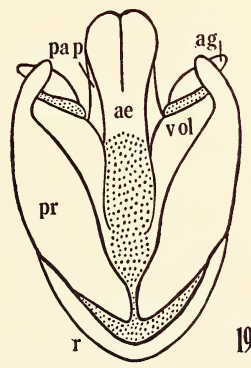Figure 13. Hind wing.
Figure 14. Pretarsus of the hind leg.
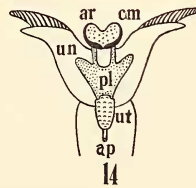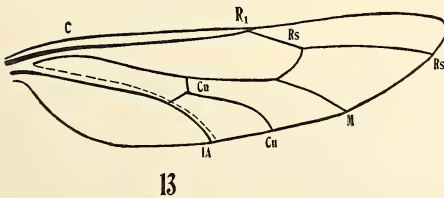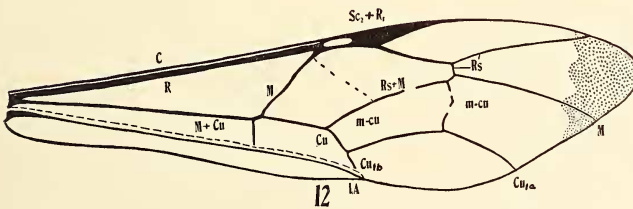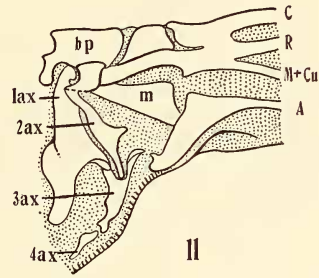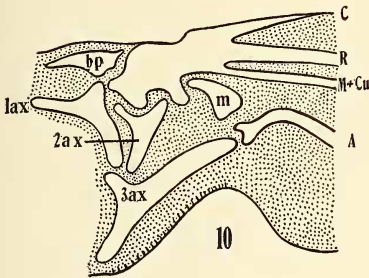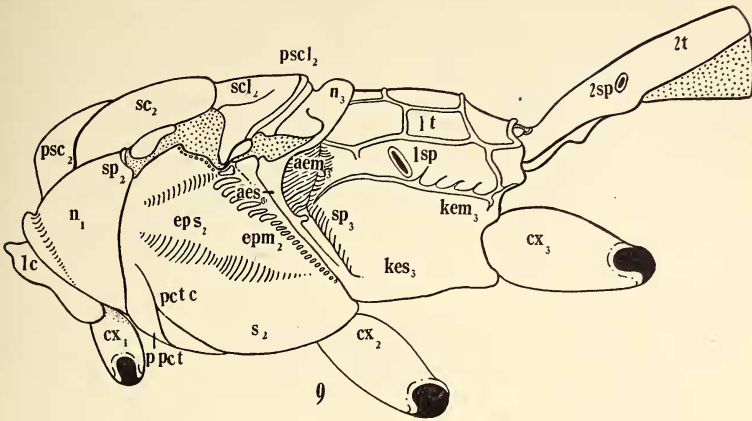
Plate VII

Figure 15. Lateral view of the female abdomen (ovipositor and sheaths cuts off at tip of the abdomen).
Figure 16. Lateral view of the female genitalia.
Figure 17. Lateral view of the male abdomen.
Figure 18. Dorsal view of the male genitalia.
Figure 19. Ventral view of the male genitalia.